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New records of invasive hammerhead flatworms (Platyhelminthes, Geoplanidae, Bipaliinae) from Mexico using a citizen science platform, with an identification key to the species found in North America

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Abstract

We present new records of the invasive hammerhead flatworms *Bipalium kewense* Moseley, 1878 and *Bipalium vagum* Jones & Sterrer, 2005 (Platyhelminthes, Geoplanidae, Bipaliinae) from several states in Mexico based on iNaturalist and two vouchered specimens. This represents for Mexico the first review of distribution records of this group and highlights the importance of citizen science in monitoring the distribution of these ecologically important invasive predators. Methods for the collection and preservation of hammerhead flatworms, as well as an identification key, are proposed.

Keywords

Bipalium kewense, *Bipalium vagum*, Continenticola, *Diversibipalium*, Terricola, Tricladida

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Introduction

Among the many taxa that comprise the phylum Platyhelminthes (flatworms), only one family, Geoplanidae Stimpson, 1857, has been able to truly colonize terrestrial ecosystems (Winsor et al. 1998). This family of free-living carnivores, commonly known as land planarians or terrestrial flatworms, is currently divided into five subfamilies, of which Bipaliinae Stimpson, 1857 is easily distinguished from the others by the presence of a greatly widened and conspicuous head (Fig. 1), earning them the common name of hammerhead flatworms

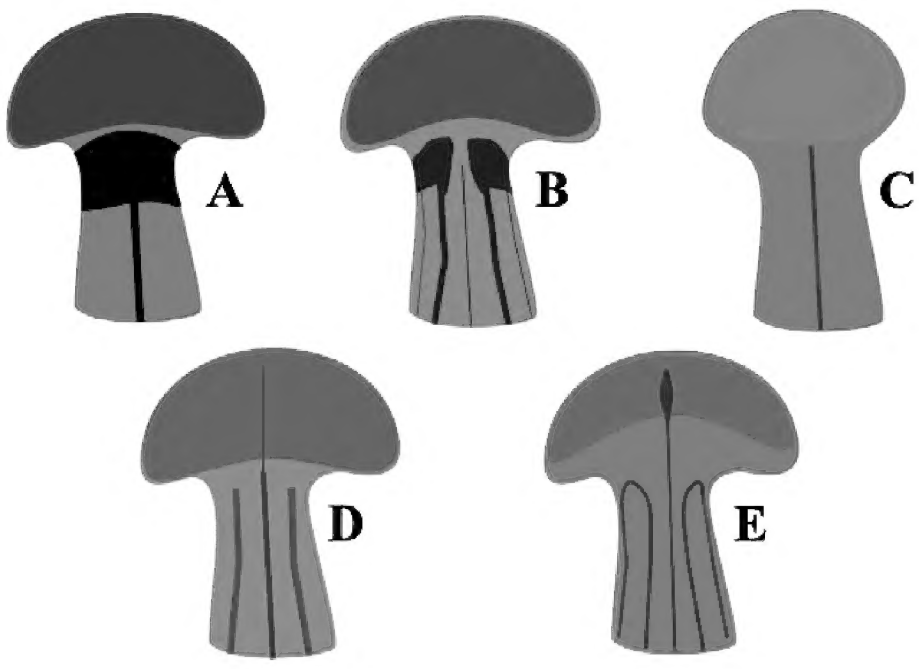

Figure 1. Illustrations of the dorsal aspect of the heads and necks of the five species of hammerhead flatworm (Geoplanidae, Bipaliinae) that have been recorded for North America. **A.** *Bipalium vagum*. **B.** *Bipalium kewense*. **C.** *Bipalium adventitium*. **D.** *Bipalium pennsylvanicum*. **E.** *Diversibipalium multilineatum*.

(Álvarez-Presas et al. 2014).

Hammerhead flatworms are native to the island of Madagascar as well as Southeast Asia, from India to Japan and including Indonesia and the Philippines (Ogren and Kawakatsu 1987). However, several species have been accidentally introduced to several countries around the globe (Fig. 2), where they are considered invasive (Álvarez-Presas et al. 2014). Hammerhead flatworms are important predators of soft-bodied soil fauna, particularly earthworms and gastropods (Ducey et al. 1999, 2007), although they have been observed attempting predation upon tiny vertebrates such as Brahminy Blind Snake, *Indotyphlops braminus* (Daudin, 1803) (Serpentes, Typhlopidae) (Mizuno and Kojima 2017). They constitute a threat to the native soil fauna wherever they are introduced (Okochi et al. 2010; Justine et al. 2018).

Four genera of hammerhead flatworms are recognized: *Bipalium* Stimpson, 1857, *Humbertium* Ogren & Sluys, 2001, and *Novibipalium* Kawakatsu, Ogren & Froehlich, 1998, three natural genera which are differentiated by their genitalia as determined by histological examination (Kawakatsu et al. 1998, 2002; Ogren and Sluys 2001), and *Diversibipalium* Kawakatsu, Ogren, Froehlich & Sasaki, 2002, a collective genus for the currently unclassifiable hammerhead flatworms from which sufficient information on their genitalia is lacking (Kawakatsu et al. 2002). Five species of two genera are recorded as introduced invaders in North America, all of which can be differentiated by the shape of the head, size, color, and stripe pattern: *Bipalium adventitium* Hyman, 1943; *Bipalium kewense* Moseley, 1878; *Bipalium pennsylvanicum* Ogren, 1987; *Bipalium vagum* Jones & Sterrer, 2005; and *Diversibipalium multilineatum* (Makino & Shirasawa, 1983).

While there are multiple records of hammerhead flatworms for Canada (Winsor 1983; Justine et al. 2019), the USA (Hyman 1943; Ogren 1981, 1984, 1987; Winsor 1983; Ball and Sluys 1990; Ogren and Sheldon 1991; Ducey and Noce 1998), some Caribbean islands (Winsor 1983; Morffe et al. 2016; Justine et al. 2018; Reinés-Álvarez 1996; Rodríguez-Cabrera and Torres 2019), as well as other regions of the world (Baptista et al. 2010; Du Bois-Reymond 1953; Filella-Subirà 1983; Justine et al. 2018, 2022; Sánchez-García 2014; Negrete et al. 2012; Okochi et al. 2010; Wu et al. 2005), there is almost no information on this subfamily in Mexico. We were unable to find more than a single formal record for the country (Winsor 1983).

Methods

Collection, recording and fixation of terrestrial flatworms. We followed the methodology described by Winsor (1998). Upon finding a specimen either resting under rocks, wood, or debris, or active at night

Figure 2. Countries and territories with records of *Bipalium kewense* (red), *Bipalium vagum* (blue) or both (purple) in the literature. Map made using SimpleMappr (Shorthouse 2010). The colored area only reflects the presence of the species but not its distribution within the countries. More detailed records for each country, including some of the records presented herein, are available on GBIF (*B. kewense*: https://www.gbif.org/species/2502938; *B. vagum*: https://www.gbif.org/species/6476069).

(especially during rainy and foggy weather), we placed it, individually, in a clean container (centrifuge tubes, test tubes, etc.) with some moist leaf litter or moss, and kept it in a cool, dark place. We then transported it to the workstation and placed it in a Petri dish filled to the brim with tap water and photographed it in a distended state. Following this, we drained the water and added a weak ethanol solution (~5%). This caused somewhat violent contractions in the specimen but anesthetized it in 10–20 min. After the specimen ceased movement and no longer reacted to stimuli, we carefully straightened it and photographed it (dorsally and ventrally) in this relaxed state.

Following the anesthetization process, we drained the weak ethanol solution and added "Winsor fixative" to the brim. This solution is hereby named after researcher Leigh Winsor, who proposed this modification of Tyler's fixative to fix terrestrial flatworms (Winsor 1998). It consists of 1-part commercial formaldehyde (37–40%) and 9-parts tap water, adding 20 g of anhydrous calcium chloride and 2 g of either cobalt chloride or cobalt nitrate for each liter of solution. If this solution is not available, carefully pouring boiling water on the living specimen and then placing it in commercial 70–96% ethanol or 8–10% commercial formaldehyde can be done instead. After the fixing media was added, the lid was placed on the Petri dish. The specimens are extremely fragile at this stage; therefore, care must be given in moving the Petri dish as little as possible, at least for the first 48 hours. The specimen is then left in the medium for at least a week, two if possible, refilling it when necessary. The specimens can be stored in Winsor's fixative at ambient temperature almost indefinitely but should not be stored in 8–10% commercial formaldehyde alone for more than 48 hours, as in our experience, it turns the specimens very hard and brittle. After fixation, the specimen was carefully washed in tap water and placed in 70% ethanol for long-term storage. Other histological techniques are explored in Winsor and Sluys (2018).

Correctly labeling of specimens is critical and must be done on water-resistant paper, with the data written with a pencil or solvent-resistant ink. It is important to add georeferenced locality data, date of collection, the collector's name, the fixing media, and codes for the photographs taken. The label must be inside the vial with the specimen, never on the outside. After specimens are properly prepared, photographed both dorsally and ventrally, and labeled, they should be deposited in museums or university collections, preferably those with collections of soil invertebrates or that have experts working on terrestrial flatworms.

The two physical vouchers were deposited in the Entomology Laboratory of the Facultad de Ciencias Forestales (FCF) of the Universidad Autónoma de Nuevo León (UANL) under the codes GEOPL001 and GEOPL002.

Records from iNaturalist. Records in this citizen science app were reviewed manually, searching for phylum Platyhelminthes, family Geoplanidae, subfamily Bipaliinae, as well as the genera *Bipalium*, *Humbertium*, *Novibipalium*, and *Diversibipalium*; the searches were limited to Mexico, including its islands. Those with obscured locality data were excluded from this study. A database was created using the 269 records found (190 for *Bipalium kewense* and 79 for *Bipalium vagum*). The determination of the species was corroborated using original and subsequent descriptions (Hyman 1943; Makino and Shirasawa 1983; Winsor 1983; Ogren 1987; Ball and Sluys 1990; Jones and Sterrer 2005; Justine et al. 2018; Wallace and Winsor 2020), from which an artificial identification key that employs external charac-

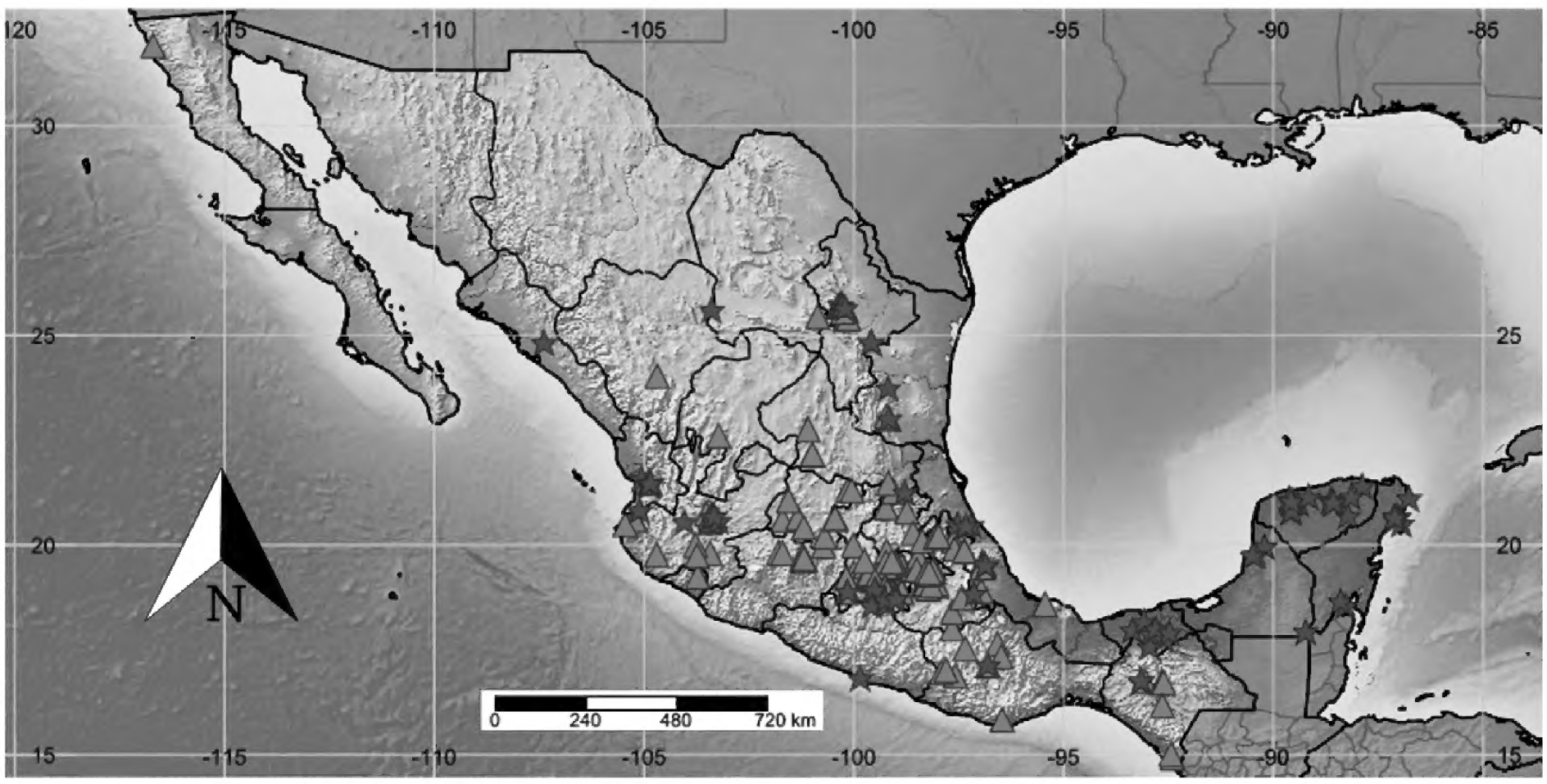

Figure 3. New records in Mexico for *Bipalium kewense* (red triangles) and *Bipalium vagum* (blue stars). Map made using SimpleMappr (Shorthouse 2010).

ters was also created. The complete link (https://www.inaturalist.org/observations/) for each iNaturalist observation is abbreviated with the symbol # in the records list. The maps showing the records of the species were made using the website SimpleMappr (Shorthouse 2010).

Results

***Bipalium kewense* Moseley, 1878**
Figures 1B, 2–4

Material examined. MEXICO – **Tamaulipas** • Reserva de la Biosfera "El Cielo", gardens of the Centro Interpretativo Ecológico (CIE), of Gomez Farias; 23.0066, −099.1684; 819 m alt.; 5.VII.2020; Manuel de Luna and Roberto García-Barrios leg.; active on a rainy night (around 02:00), fixed in Winsor's fixative (specimen was already dead before fixation), GEOPL001.

Figure 4. Dorsal aspect of the head and neck of *Bipalium kewense*, diagnostic of the species. Specimen GEOPL001, post fixation.

iNaturalist records. MEXICO – **Baja California** • El Sauzal, Ensenada; 31.8989, −116.6995; 14 m alt.; 30.V.2020, oscarjimenez obs.; #47845508 – **Chiapas** • San Cristobal de las Casas; 16.7171, −092.6444; 2117 m alt.; 21.VII.2014; juarez120190 obs.; #795463 • Tapachupla, 14.9237, −092.4081; 23 m alt.; 31.X.2021; villanuevagr obs.; #99900322 • Tuxtla Gutiérrez; 16.7544, −093.0592; 663 m alt.; 27.IX.2020; jmmelendez obs.; #62027393 • Barrio de Fátima, San Cristobal de las Casas; 16.7248, −092.6504; 2115 m alt.; 15.VII.2020; jessyoscarobs.; #53194334 • Real del Monte, San Cristobal de las Casas; 16.7131, −092.6126; 2142 m alt.; 12.VII.2019; laurenzarate obs.; #29225588 • San Cristobal de las Casas; 16.1717, −092.6444; 2114 m alt.; 21.VII.2014; juarez120190 obs.; #795463 • Hueguetlán; 15.0154, −092.4358; 27 m alt.; 21.VIII.2014; giezianthony obs.; #17223154. **Ciudad de México** • Mayorazgo de los Gigantes, Ciudad López Mateos; 19.5746, −099.2218; 2275 m alt.; 25.VIII.2021; carolinaestradagutierrez obs.; #92471051 • 10 de Mayo; 19.4342, −099.1208; 2235 m alt.; 6.IX.2021; pabloevd obs.; #93902085 • Tlalpan; 19.2790, −099.2114; 2535 m alt.; 2.V.2013; annemirdl obs.; #438193 • Viveros de Coyoacán, Coyoacán; 19.3536, −099.1715; 2259m. a.s.l.; 4.VII.2014; leticiamercadogaribay obs.; #793937 • cerca de Avenida Unión, Tlalpán; 19.3029, −099.2201; 2435 m alt.; 8.VII.2015; crisg obs.; #1767872 • Parque Ecológico Experimental, Coyoacán; 19.3176, −099.1726; 2269 m alt.; 8.X.2015; martznatalia obs.; #2406091 • Copilco el Alto, Coyoacán; 19.3318, −099.1753; 2268 m alt.; 8.VI.2017; alondrafn obs.; #6549611 • Calle Cerro de la Mano, Coyoacán; 19.3385, −099.1726; 2263 m alt.; 8.VII.2015; jsainz obs.; #7107593 • Parque Nacional Bosque de Pedregal, Tlalpan; 19.2872, −099.1964; 2413 m alt.; 25.II.2018; jluis2503 obs.; #10013991 • Ciudad Universitaria, Coyoacán; 19.3189, −099.1728; 2270 m alt.; 23.V.2018; jorch66 obs.; #12798800 • Av. Universidad, Coyoacán, 19.3364, −099.1875; 2288 m alt.; 19.VI.2018; m00ncanddy obs.; #13589318 • Plaza de las Vizcaínas, Cuauhtémoc; 19.4276, −099.1407; 2235 m alt.; 6.VIII.2018; mon43 obs.; #15173450 • Viveros de Coyoacán, Coyoacán; 19.3539, −099.1704; 2258 m alt.; 22.I.2012; paulmartinez2 obs.; #16862128 • Plaza de las Vizcaínas, Cuahutémoc; 19.4277, −099.1405; 2237 m alt.; 25.IX.2018; yanly obs.; #16915820 • Calle Hortensia, Álvaro Obregón; 19.3566, −099.1833; 2271 m alt.; 9.XI.2018; deni_etxe obs.; #18308124 • Coyoacán; 19.3250, −099.1794; 2271 m alt.; 20.XI.2018; anakarenmartnezlara obs.; #19235601 • Avenida año de Juárez, Xochimilco; 19.2604, −099.0299; 2250 m alt.; 5.XI.2018; educadoreang obs.; #20806119 • Calle Saye 6-C, Tlalpan; 19.2978, −099.2301; 2501 m alt.; 25.IV.2019; priscila27 obs.; #23072725 • Santa Fe, Álvaro Obregón; 19.3684, −099.2641; 2542 m alt.; 7.VIII.2019; lorena28 obs.; #30374776 • Bosque de Chapultepec, Miguel Hidalgo; 19.4175, −099.1836; 2258 m alt.; 16.VIII.2019; g1rt4b obs.; #30943319 • Calle Cerro de la Mano 38, Coyoacán; 19.3385, −099.1726; 2263 m alt.; 25.VIII.2019; jsainz obs.; #31505081 • Del Carmen, Coyoacán; 19.3551, −099.1701; 2259 m alt.; 26.X.2019; joelgr obs.; #35060716 • Coyoacán; 19.3166, −099.1953; 2329 m alt.; 23.I.2020; gisel_15 obs.; #38029338 • San Andrés Ahuayucan, Xochimilco; 19.2237, −099.1044; 2427 m alt.; 21.XI.2020; alejandro_fb obs.; #78639522 • Ajusco, Coyoacán; 19.3218, −099.1614; 2280 m alt.; 14.IV.2021; joancarlos obs.; #74149041 • Ciudad Universitaria, Coyoacán; 19.3203, −099.1728; 2272 m alt.; 15.XI.2017; dani_mg obs.; #67741299 • Atizapán de Zaragoza; 19.5605, −099.2457; 2289 m alt.; 6.XII.2020; Oswaldo Maldonado Flores obs.; #66220766 • Parque Nacional Bosque de Pedregal, Tlalpan; 19.2875, −099.2100; 2476, a.s.l.; 1.X.2020; dani_mg obs.; #61449108 • La Draga, Tlalpan; 19.2819, −099.0421; 2241 m alt.; 23.VIII.2020; joelgr obs.; #57479509 • Condominios del Bosque, Tlalpan; 19.2960, −099.1890; 2304 m alt.; 21.VIII.2020; davidcruz82, #54458163 • Amp. Cuchilla Tepecimilpa, Tlalpan; 19.2692, −099.1926; 2691 m alt.; 29.V.2020; leonday_jlda obs.; #40996897 • Amp.

Ramos Millán, Iztacalco; 19.3869, −099.0994; 2239 m alt.m; 28.IX.2021; _perez-montes obs.; #96481475 • Bosque de Tlalpan, Tlalpan; 19.2937, −099.1985; 2384 m alt.; 7.X.2021; Luis_antonio_manjarrez_ayala obs.; #97453411 • La Casilda, Gustavo A. Madero; 19.5581, −099.1297; 2312 m alt.; 19.IX.2021; miryamlimareyes obs.; #95417849 • Magdalena Contreras; 19.3255, −099.2293; 2433 m alt.; 9.VIII.2021; renata_rovelo obs.; #90526930 • Coyoacán; 19.3495, −099.1510; 2244 m alt., 22.VII.2021; diego_apalategui obs.; #88153845 • Iztapalapa; 19.3408, −099.9986; 2356 m alt.; 1.VII.2021; mireyaglezr obs.; #85253105 – **Coahuila** • Ciudad Universitaria de Universidad Autónoma de Coahuila, Arteaga; 25.4432, −100.8598; 1650 m alt.; 15.V.2019; lizethlizeth obs.; #25159173 – **Colima** • Colima; 19.2423, −103.7221; 498 m alt.; 11.X.2019; stefannielle obs.; #34231408. **Durango** • Parque Guadiana, Durango; 24.0252, −104.6875; 1900 m alt.; 3.X.2021; another_hematophilic obs.; #97186613 – **Estado de México** • Naucalpan de Juárez; 19.4333, −099.2358; 2355 m alt.; 02.IX.2016; christian77amador obs.; #4019452 • near Club de Golf Chapultepec, Naulcalpan de Juárez; 19.4843, −099.2044; 2356 m alt.; 2.IX.2016; christian77amador obs.; #4019671 • Residencial Chiluca, Atizapán de Zaragoza; 19.5426, −099.3022; 2499 m alt.; 7.X.2016; eloirhdz obs.; #4291351 • Los Pastores 53340; Naucalpán de Juárez; 19.4817, −099.2217; 2266 m alt.; 30.IX.2017; medievil602 obs.; #8190430 • Calle Andrómeda 50, Naucalpán de Juárez; 19.5132, −099.2570; 2348 m alt.; 22.VIII.2018; editheli obs.; #15790270 • Parque Naucalli, Naucalpán de Juárez; 19.4934, −099.2399; 2269 m alt.; 28.X.2018; luispacheco89 obs.; #17918151 • Tlalnepantla de Baz; 19.5235, −099.1880; 2253 m alt.; 3.XII.2018; jossvzqz obs.; #81384708 • Mayorazgo de los Gigantes, Atizapán de Zaragoza; 19.5746, −099.2218; 2275 m alt.; 25.VIII.2021; carolinaestradagutierrez obs.; #92471051 • Atizapán de Zaragoza; 19.4726, −099.2573; 2308 m alt.; XI.2021; aa_a1 obs.; #102436488 • Acambay; 19.9906, −100.0085; 2512 m alt.; 1.X.2021; manuel728 obs.; #96773677 • Texcoco; 19.5488, −098.8630; 2264 m alt.; 9.IX.2021; ylt obs.; #94238039 • Atizapán de Zaragoza; 19.5746, −099.2218; 2275 m alt.; 25.VIII.2021; carolinaestradagutierrez obs.; #92471051 • Metepec; 19.2650, −099.5647; 2590 m alt.; 14.VIII.2021; angelromeror obs.; #91329842 • Texcoco; 19.5217, −098.8738; 2255 m alt.; 3.VI.2021; zaidv23 obs.; #84492185 • Ocoyoacac; 19.2937, −099.4598, 2622 m alt.; 14.VIII.2020; danilocs obs.; #56476186 • Ixtlahuaca; 19.4968, −099.7232; 2599 m alt.; 7.VII.2020; ben_vireo obs.; #53791234 • Ecatepec de Morelos; 19.5943, −099.0120; 2240 m alt.; 16.VII.2020; d_b obs.; #53281319 • Tejupilco; 18.8990, −100.1459; 1317 m alt.; 24.VI.2020; leascelyn obs.; #50746793 • Toluca; 19.2896, −099.6812; 2730 m alt.; 25.IV.2020; biolosrherp obs.; #44075329 • Tultepec; 19.6555, −099.1409; 2251 m alt.; 27.IV.2020; harpia obs.; #43987128 • San Antonio la Isla; 19.1737, −099.5377; 2573 m alt.; 15.II.2020; cerezobedolla obs.; #40417230 • Ecatepec de Morelos; 19.5944, −099.0119; 2240 m alt.; 13.XI.2019; d_b obs.; #35808808 • Valle de Bravo; 19.2012, −0100.1746; 1819 m alt.; 7.XI.19; emilianotaco obs.; #35632969 • Valle de Bravo; 19.2066, −0100.1793; 1783 m alt.; 7.XI.2019; Legaspi; #35503535 • Toluca; 19.3136, −099.6330; 2628 m alt.; 29.IX.2019; saramartz obs.; #33636299 • Huehuetoca; 19.8511, −099.2177; 2260 m alt.; 2.V.2018; luiz_linarez obs.; #30733538 • Naucalpan de Juárez; 19.4940, −099.2381; 2280 m alt.; 13.VII.2019; alejandrocalzada obs.; #28844780 • Atizapan de Zaragoza; 19.5942, −099.2310; 2354 m alt.; 3.IX.2016; luishernndez obs.; #27418332 • Naucalpan de Juárez; 19.4934, −099.2399; 2269 m alt.; 28.X.2018; luispacheco89 obs.; #17918151 • Ixtlahuaca; 19.6150, −099.7433; 2534 m alt.; 19.IX.2018; alver obs.; #16684704 • Tejupilco, 18.8852, −100.1565; 1334 m alt.; 20.V.2018; leascelyn obs.; #12646271 • Parque Residencial Coacalco, Coacalco de Berriozabal; 19.6105, −099.0895; 2420 m alt.; 8.VIII.2017; tari obs.; #7412478 • Almomoya del Río; 19.1554, −099.4946; 2571 m alt.; 12.IX.2010; noepacheco obs.; #3723796 • Malinalco; 18.9482, −099.4858; 1736 m alt.; 2.IX.2015; biosfera3 obs.; #1913244 – **Hidalgo** • Parque Nacional Los Mármoles, Zimapán; 20.8933, −099.2313; 2115 m alt.; 12.XI.2021; adal_franco obs.; #101516450 • Apan; 19.7169, −098.4667; 2468 m alt.; 20.X.2021; alx8 obs.; #99166406 • Molango de Escamilla; 20.7861, −098.7326; 1563 m alt.; 10.IX.2021; liliaminervafarfanbautista obs.; #94321952 • Huasca de Ocampo; 20.2832, −098.5865; 1936 m alt.; 11.VIII.2020; plantserrli obs.; #57282418 • Tulacingo de Bravo; 20.0904, −098.3690; 2155 m alt.; 1.XI.2015; alejandrod obs.; #2389545 – **Guanajuato** • La Regalada, Cuerámaro; 20.6018, −101.6959; 1811 m alt.; 5.X.2021; oskuikvarredondo obs.; #97504159 • Residencial Floresta, Irapuato; 20.6465, −101.3351; 1721 m alt.; 19.VI.2021; fatima_tornero obs.; #83642703 • San Mateo Tócuaro, Acámbaro; 19.9687, −100.7242; 2380 m alt.; 30.X.2020; pancholinjaime obs.; #64386083 • Xichú, 21.3027, −100.1426; 2561 m alt.; 30.I.2020, edhy obs.; #38121412 • San Luis; 20.1933, −100.6911; 2229 m alt.; 12.X.2019; girlruiz85 obs.; #34701395 • Valle de Santiago; 20.4151, −101.1923; 2093 m alt.; 23.IX.2019; marisolgr obs.; #33261078 • Héroes de León, León; 21.0599, −101.5570; 1844 m alt.; 30.VIII.2019; gustavorivera obs.; #31870295 • Xichú; 21.2940, −100.0457; 2561 m alt.; 15.I.2019; calliepillar obs.; #19715124 – **Jalisco** • Villa Purificación; 19.7710, −104.7004; 443 m alt.; 7.XI.2021; pedro_morales obs.; #101170902 • Herradura, Puerto Vallarta; 20.6184, −105.2184; 91 m alt.; 19.IX.2021; biologopatasalada obs.; #95699657 • Tamazula de Gordiano; 19.7989, −103.4252; 2108 m alt.; 11.IX.2021; davidismael28 obs.; #94663223 • Tapalpa; 19.9953, −103.7747; 2184 m alt.; 25.XII.2020; esolana obs.; #67051077 • El Caloso, Puerto Vallarta; 20.6082, −105.2251; 44 m alt.; 6.XII.2020; jair_6 obs.; #66683378 • Tlajomulco de Zuñiga; 20.5368, −103.4345; 1563 m alt.; 26.X.2020; mancilla16 obs.; #63587294 • Barrio de la Quinta, San Gabriel; 19.7512, −103.7381; 1268 m alt.; 27.IX.2017; porfirio1 obs.; #36662532 • Cabo Corrientes; 20.4876, −105.4494; 36 m alt.; 26.XI.2019;

lzo obs.; #36102103 • Zapopan; 20.7340, −103.3868; 1565 m alt.; 20.XI.2019; apollolens obs.; #35894373 • Tlaquepaque; 20.5957, −103.3914; 1588 m alt.; 28.X.2019; paulspawl obs.; #35067957 • Las Agujas, San Juan de Ocotán; 20.7460, -103.5128; 1659 m alt.; 1.X.2019; gabrielgonzalezc obs.; #34284517 • Guadalupe Jarzín, Zapopan; 20.6606, −103.4274; 1641 m alt.; 22.VI.2018; pisterman obs.; #13811317 • Zapopan; 20.6890, −103.3319; 1538 m alt.; 16.IX.2016; barbaratejeda obs.; #4134069 – **Michoacan** • Ejercito Liberal, Morelia; 19.7261, −101.2263; 1935 m alt.; 27.IX.2021; nilosignoro obs.; #96428114 • Tenencia Morelos, Morelos; 19.6460, −101.2438; 1943 m alt.; 14.VI.2021; daniel2614 obs.; #86993782 • Morelia; 19.6438, −101.2269; 1998 m alt.; 12.IX.2020; guadalupe_cornejo_tenorio obs.; #66757255 • Zacapu; 19.8148, −101.7893; 1994 m alt.; 01.VIII.2020; fannycoria obs.; #55068078 • Avenida Plan de Ayala, Jesús del Monte, Morelia; 19.6516, −101.1578; 2116 m alt.; 19.X.2019; nilosignoro obs.; #34626876 • Guadalupe, Morelia; 19.7064, −101.2267; 1908 m alt.; 27.IV.2019; isabel_soria obs.; #23554787 • Morelia; 19.6736, −101.1844; 2055 m alt.; 5.XI.2018; jorgegomezguzman obs.; #19063606 • Colonia Félix Ireta, Coeneo; 19.8068, −101.6959; 1992 m alt.; 1.IX.2018; elrayman210 obs.; #16145076 – **Morelos** • Los Reyes, Yecapixtla; 18.8809, −098.8596; 1600 m alt.; 3.X.2021; carlos1357 obs.; #97081428 • Yautepec de Zaragoza; 18.8872, −099.0452; 1220 m alt.; 5.II.2021; florecitasil obs.; #69137647 • Yautepec de Zaragoza; 18.8888, −099.0784; 1268 m alt.; 4.XI.2020; fernanda_g_rivera obs.; #64579486 • Lomas de Chamilpa, Cuernavaca; 18.9871, −099.2419; 1937 m alt.; 3.VIII.2020; nancyrodrguez obs.; #55322502 • Huitzilac; 19.0082, −099.2414; 2270 m alt.; 5.X.2019; emmanuelsaag obs.; #33897052 • Jiutepec; 18.8990, −099.2075; 1418 m alt.; 12.XI.2017; emmanuelsaag obs.; #8782363 – **Nayarit** • Instituto Tecnológico de Tepic, Tepic; 21.4779, −104.8656; 926 m alt.; 7.XII.2018; egodaz obs.; #18891569 – **Nuevo Leon** San Jerónimo, Monterrey; 25.6817, −100.3634; 597 m alt.; 2.X.2021; eleonora70 obs.; #96893676 • Pedregal del Topo Chico, General Escobedo; 25.8065, −100.3609; 550 m alt.; 29.VIII.2021; alexcsn obs.; #92958657 • Calle Sevilla, Monterrey; 25.6914, −100.3790; 697 m alt.; 6.IX.2020; cecyramos obs.; #58728418 • Santiago; 25.3795, −100.2085; 1533 m alt.; 26.VIII.2020; carlsgc_1251 obs.; #57879728 • Cascadas del Cerro de la Silla, Guadalupe; 25.6294, −100.2099; 622 m alt.; 5.X.2019; memorodriguez obs.; #39870812 • Gran Parque San Nicolás, San Nicolás de los Garza; 25.7357, −100.2929; 506 m alt.; 7.III.2020; aztekium_tutor obs.; #39780444 • Gran Parque San Nicolás, San Nicolás de los Garza; 25.7363, −100.2925; 505 m alt.; 7.III.2020; briseida obs.; #39664523 • Carretera a Montebello, Juárez; 25.5940, −100.1853; 554 m alt.; 11.X.2019; jmfindingo obs.; #34235487 • Ciudad Universitaria, San Nicolás de los Garza; 25.7241, −100.3162; 529 m alt.; 31.VIII.2017; roger_rh obs.; #7975070 • El Cercado, Santiago; 25.4075, −100.1314; 450 m alt.; 18.III.2017; pedro_alanis obs.; #5394596 • El Lienzo, Zitoon, Gudalupe; 25.6743, −100.2410; 485 m alt.; 17.XII.2016; memorodriguez obs.; #5021042 • Camino Antiguo a Valle Alto, La Estanzuela, Monterrey; 25.5499, −100.2704; 701 m alt.; 27.VIII.2016; fatima2 obs.; #5015578 • Ciudad Universitaria, San Nicolás de los Garza; 25.7239, −100.3161; 529 m alt.; 4.X.2016; yajazielhdz obs.; #4311349 – **Oaxaca** • Santiago Yosondúa; 16.8761, −097.5767; 2191 m alt.; 15.VII.2021; yese-san obs.; #93001387 • San Juan Bautista Suchitepec; 18.0125, −097.6579; 1954 m alt.; 5.VIII.2021; francisco255 obs.; #92508259 • Carretera E.C., El Sesteadero, Putla Villa de Guerrero; 16.9581, −097.9139; 752 m alt.; 10.I.2021; agaporni obs.; #67865183 • San Francisco la Reforma, San Pedro Yolox; 17.6410, −096.5721; 1674 m alt.; 30.IX.2020; cristina_lopez_garcia obs.; #62612644 • San Lorenzo Cacaotepec; 17.1271, −096.8064; 1602 m alt.; 24.VIII.2020; synodontis obs.; #57461770 • Calle Gómez Farías, Ixtlán de Juárez; 17.3324, −096.4855; 2503 m alt.; 7.X.2017; estromatojorge obs.; #8343653 • San Pedro Pochutla; 15.8286, −096.4646; 231 m alt.; 27.VIII.2016; bernabe obs.; #4411156 • Santa María Yucuhiti; 17.0037, −097.7992; 1759 m alt.; 10.IX.2016; coatzin_tutor obs.; #4105733 • Santo Domingo Yanhuitlán; 17.5262, −097.3438; 2152 m alt.; 9.X.2013; cex obs.; #449364 – **Puebla** • San Nicolás Tepoxtitlán, Atexcal; 18.4019, −097.6526; 2436 m alt.; 27.XII.2021; mixtk obs.; #103930008 • Santa Lucía; 18.9576, −098.2285; 2100 m alt.; 18.XII.2020; bicharracos_que_me_encuentro obs.; #100794915 • Residencial Club de Golf "La Huerta", San Pedro Cholula; 19.0602, −098.3315; 2164 m alt.; 9.X.2021; drimar obs.; #97732928 • Centro Huehuetla, Huehuetla; 20.1067, −097.6246; 564 m alt.; 5.V.2021; biolarmando12 obs.; #95999022 • Zacapoaxtla; 19.9041, −097.6004; 1583 m alt.; 21.III.2021; erikavazquezflores obs.; #71733972 • Teziutlán; 19.8549, −097.3653; 1680 m alt.; 20.III.2021; mario150601 obs.; #71663198 • Teziutlán; 19.8522, −097.3639; 1669 m alt.; 18.III.2021; mario150601 obs.; #71520485 • San José de la Laguna, Amozoc; 19.0297, −098.0366; 2313 m alt.; 23.VIII.2020; adriana_duarte06 obs.; #59066745 • Santa Monica Sur, San Pedro Cholula; 19.0677, −098.2899; 2145 m alt.; 9.IX.2020; pedrocervantes obs.; #59037039 • Tlahuapan; 19.4063, −098.4994; 2181 m alt.; 5.VIII.2020; ivettemoreno obs.; #55527684 • Amozoc; 19.0763, −098.0300; 2113 m alt.; 7.VIII.2020; dago628 obs.; #53115023 • INFONAVIT Amalucan, Puebla; 19.0486, −098.1513; 2195 m alt.; 2.XII.2019; alejandro255 obs.; #36294425 • Huachingo; 20.1757, −098.0628; 1556 m alt.; 20.IV.2018; octpemo obs.; #18315826 • Huachingo; 20.2043, −097.9797; 1289 m alt.; 16.IX.2018; menito2003jr obs.; #16644837 • Calle El Arenal, Cañada Morelos; 18.7407, −097.4229; 2297 m alt.; 9.II.2018; alexiz obs.; #9798561 – **Queretaro** • Santiago de Querétaro; 20.6094, −100.4542; 1802 m alt.; 30.XI.2021; arturovega obs.; #102256463 • Landa de Matamoros; 21.2660, −099.0566; 903 m alt.; 25.IX.2021; ezau obs.; #96182568 • Santiago de Querétaro; 20.6557, −100.4419; 1822 m alt.; 22.VIII.2021; orishiku obs.; #92063053 • Jalpán de Serra; 21.4649, −099.1785; 1262 m alt.;

10.X.2018; crisperalta obs.; #38634614 • Lomas de Satélite, Santiago de Querétaro; 20.6419, −100.4474; 1839 m alt.; 16.XI.2019; gildardojg obs.; #35740043 – **San Luis Potosí** • Tangamanga; 22.1391, −100.9922; 1876 m alt.; 9.VI.2021; luisstevens obs.; #87073695 • Los Ángeles; 22.1567, −100.9855; 1872 m alt.; 9.VII.2021; karenmores obs.; #86349979 • Colonia Las Lomas, Moctezuma; 22.7470, -101.0924; 1748 m alt.; 27.X.2018; ramiro8 obs.; #17896099 – **Tamaulipas** • Reserva de la Biosfera "El Cielo", Valle del O.V.N.I., Gomez Farias; 23.0587, −099.2275; 1329 m alt.; 27.IX.2020; jmfindigo obs.; #61274277 – **Tlaxcala** • San Lucas Cuahtelupan, Tlaxcala; 19.2960, −098.2662; 2287 m alt.; 18.IX.2020; axlramone obs.; #60028329 • San Lucas Cuahtelupan, Tlaxcala; 19.3080, −098.2062; 2217 m alt.; 12.IX.2014; azulcasimorado obs.; #39253443 • San Francisco Temetzontla, Panotla; 19.3531, −098.2831; 2607 m alt.; 11.XI.2019; jessicavazquez obs.; #35573932 • San Miguel Contla, Santa Cruz Tlaxcala; 19.3700, −098.1285; 2351 m alt.; 2.X.2019; tannyaramosmendoza obs.; #34052032 • Tetla de la Solidaridad; 19.4621, −098.0953; 2544 m alt.; 11.X.2016; Israel_piedras_gtz obs.; #9732757 • San Andrés Ahuashuatepec, Tzompantepec; 19.3954, −098.1162; 4.X.2019; iveth_del_angel obs.; #34044320 • Cuahuatzala, San Esteban Tizatlán; 19.3458, −098.2030; 2286 m alt.; 19.X.2016; checo199303 obs.; #4394945 – **Veracruz** • Jardín Botánico Francisco Javier Clavijero, Xalapa; 19.5135, −096.9408; 1333 m alt.; 19.X.202;1; jorge_ramos obs.; #98762502 • Calle Rubí, Coatepec; 19.4489, −096.9481; 1159 m alt.; 19.VII.202; 1; david_castillo obs.; #87736750 • Villareal, Xalapa; 19.5356, −096.9446; 1369 m alt.; 28.VI.2021; eloys obs.; #85009734 • Xalapa; 19.5460, −096.9304; 1462 m alt.; 26.II.2021; martngarcs obs.; #70515052 • Xalapa; 19.5424, −096.9322; 1443 m alt.; 25.II.2021; guillermo_alejandro obs.; #70135441 • Las Palmas, Fortín de las Flores; 18.9075, −096.9610; 958 m alt.; 19.IX.2020; axelf-m obs.; #60288260 • Francisco Ferrer Guardia, Xalapa; 19.5422, −096.9367; 1429 m alt.; 12.V.2020; alberto_lozano obs.; #52753936 • Ángel R. Cabada; 18.5889, −095.4421; 27 m alt.; 11.II.2019; paleo obs.; #20799047 • Calle Joaquín Ramirez Cabalas, Xalapa; 19.5559, −096.9170; 1453 m alt.; 26.I.2018; emmanuel39 obs.; #9619414 • Andador Televisión Mas, Xalapa; 19.5665, −096.9338; 1495 m alt.; 19.XII.2017; vet-adrianh-orozco obs.; #9222068 • Xalapa; 19.5268, −096.9347; 1377 m alt.; 15.VIII.2017; isabel_herrera obs.; #7511718 • Andador Televisión Mas, Xalapa; 19.5660, −096.9335; 1482 m alt.; 28.VI.2017; vet-adrianh-orozco obs.; #6860245 • Coatepec; 19.4694, −096.9486; 1202 m alt.; 3.X.2016; alberto_lozano obs.; #4372470 • Coatepec; 19.4700, −096.9479; 1197 m alt.; 7.VI.2016; alberto_lozano obs.; #3415038 – **Zacatecas** • El Chiquihuite, Susticacán, 22.5970, -103.2244; 2216 m alt.; 24.IX.2016; humberto15 obs.; #8303539.

Identification. A very long species, up to 80 cm. Head laterally expanded into a semilunate headplate with recurved lappets. Dorsal ground color light brown; head with the same color of the dorsum or slightly darker. Dorsum with five longitudinal black to dark-gray or dark-brown stripes, median, paired lateral and paired marginal. Median stripe black, narrow, and well-marked; it starts behind neck and broadens over pharyngeal area. Lateral stripes lighter, broader, and with diffuse margins. Marginal stripes narrow, dark, and well-marked. Lateral and marginal stripes of each side unite behind neck to form an incomplete collar (Figs. 1B, 4). Ventral surface light-ochre, with white creeping sole distinct, ridged, and delineated by paired, narrow, diffuse grayish, longitudinal stripes which extend from the ventral portion of the collar to the posterior end; collar interrupted on each side of creeping sole (Winsor 1983; Justine et al. 2018).

Distribution in Mexico. Recorded from Baja California, Chiapas, Ciudad de México, Coahuila, Colima, Durango, Estado de México, Guanajuato, Hidalgo, Jalisco, Michoacán, Morelos, Nayarit, Nuevo León, Oaxaca, Puebla, Querétaro, San Luis Potosí, Tamaulipas, Tlaxcala, Veracruz, and Zacatecas

Bipalium vagum Jones & Sterrer, 2005

Figures 1A, 2, 3, 5

Material examined. MEXICO – **Tamaulipas** • Reserva de la Biosfera "El Cielo", gardens of the Centro Interpretativo Ecologico CIE, Gomez Farias; 23.0066, −099.1684; 819 m alt.; 5.VII.2020; Manuel de Luna and Roberto García-Barrios leg.; active on a rainy night (around 00:00), fixed in Winsor's fixative, GEOPL002.

iNaturalist records. MEXICO – **Campeche** • cerca de "Alacranes", Calakmul; 17.9317, −089.2264, 69 m alt.; 16.XII.2020; Maricruz_juarez1 obs.; #74080154 • Tenabo; 19.9632, −090.2046; 16 m alt.; 27.VII.2021; carloskumijangos obs.; #88890341 • San Antonio Bobolá, Campeche; 19.7705, −090.4189; 21 m alt.; 13.IX.2021;

Figure 5. Dorsal aspect of the head and neck of *Bipalium vagum*, diagnostic of the species. Specimen GEOPL002, prior to anesthetization.

amayrani_flores obs.; #94764836 • San Pedro, Chiná; 19.7559, −090.4917; 13 m alt.; 9.IX.2019; gesmex obs.; #36727922 – **Chiapas** • Belisario Domínguez, Tuxtla Gutiérrez; 16.7385, −093.1600; 635 m alt.; 15.X.2021; jocelop obs.; #98308919 • Tapachula; 16.7518, −093.1029; 522 m alt.; 15.IX.2021; geidyrr obs.; #94981373 • Monterreal, Tuxtla Gutiérrez; 16.7646, −093.1464; 598 m alt.; 26.X.2019; omar_riley obs.; #34918702 – **Coahuila** • cerca de "Ejido los Rodríguez", Torreón; 25.6032, −103.3936; 1130 m alt.; 9.IX.2019 oscarsanchez2 obs.; #32405916. **Estado de México** • Malinalco; 18.9398, −099.5044; 1722 m alt.; 8.III.2019; yaolina obs.; #21056569 • Tejupilco; 18.8932, −100.1479; 1309 m alt.; 22.I.2019; leascelyn obs.; #19814007. **Guerrero** • Parque el Veladero, Acapulco; 16.8273, −099.8474; 247 m alt.; 14.XI.2021; fernanda_contreras obs.; #59981512 • Acamixtla, Taxco; 18.5609, −099.5689; 1588 m alt.; 9.VII.2021; shalem_bh obs.; #52441277 – **Jalisco** • Las Palmas de Arriba, Puerto Vallarta; 20.8253, −105.1083; 129 m alt.; 12.VIII.2020; josiahmtz obs.; #56271209 • Zapopan; 20.6575, −103.4072; 1614 m alt.; 1.I.2020; benjamindelatorre obs.; #37166206 • Preparatoria Regional de Ameca, Ameca; 20.5487, −104.0390; 1240 m alt.; 16.X.2019; christian210998 obs.; #34485553 • Tonalá; 20.5663, −103.2266; 1539 m alt.; 8.X.2018; agustincamacho obs.; #17321756 – **Morelos** • Ciudad Ayala, Ticumán; 18.7326, −099.0637; 1243 m alt.; 15.X.2021; gregoryrobles obs.; #98283261 • Jojutla; 18.5828, −099.22186; 942 m alt.; 11.XI.2019; zipactli obs.; #36305516 • Puente de Ixtla; 18.6995, −099.2440; 1015 m alt.; 20.VIII.2017; carlos822 obs.; #30868265 • Josefa Ortiz de Domínguez, Moyotepec; 18.7161, −098.9915; 1161 m alt.; 17.IV.2019; ari47 obs.; #22618332 – **Nayarit** • San Blas; 21.5765, −105.0599; 483 m alt.; 28.IX.2021; asahellacero. obs.; #96471784 • Moctezuma, Tepic; 21.4879, −104.8985; 962 m alt.; 27.XI.2020; jorgebc obs.; #65989324 • Tepic; 21.4607, −104.8652; 930 m alt.; 31.VII.2020; karenvazquez obs.; #57708578 • 15 de Mayo, Tepic; 21.4807, −104.8895; 930 m alt.; 24.VIII.2019; egodaz obs.; #31899441 • Xalisco; 21.4306, −104.8782; 977 m alt.; 22.III.2019; david_amador obs.; #21790520 • Valle del Country, Tepic; 21.4840, −104.8647; 920 m alt.; 27.XII.2018; egodaz obs.; #17929072 • Tepic; 21.4669, −104.8496; 916 m alt.; 9.X.2018; kaleb14 obs.; #17363110 – **Nuevo León** • Ciudad Universitaria, San Nicolás de los Garza; 25.7241, −100.3161; 529 m alt.; 31.VIII.2017; roger_rh obs.; #7975057 • Parque Fundidora, Monterrey; 25.6778, −100.2849; 515 m alt.; 21.III.2017; aztekium obs.; #5445389 • Bosques del Rey, Monterrey; 25.6392, −100.2068; 572 m alt.; 7.IV2015; aztekium obs.; #4983149 • La Loma, Linares; 24.8292, −099.5830; 388 m alt.; 12.V.2015; juancruzado obs.; #2489824 • La Loma, Linares; 24.8296, −099.5835; 393 m alt.; 19.V.2015; juancruzado obs.; #1520565 • La Loma, Linares; 24.8289, −099.5826; 384 m alt.; 17.XII.2013; juancruzado obs.; #483394 – **Oaxaca** • San Lorenzo Cacaotepec; 17.1271, −096.8064; 1602 m alt.; 28.VII.2021; synodontis obs.; #88975907. **Quintana Roo** • Calle Chakay, Solidaridad; 20.6707, −087.0405; 9 m alt.; 2.XII.2021; fam_marin_flores obs.; #102383026 • Solidaridad; 20.6036, −087.0938; 10 m alt.; 4.IX.2021; istvan7 obs.; #101725234 • Playa del Carmen; 20.6112, −087.0874; 11 m alt.; 31.I.2006; steve_orridge obs.; #67459867 • Calle Siaan Kanab, Solidaridad; 20.6693, −087.0418; 11 m alt.; 8.XII.2020; fam_marin_flores obs.; #66351338 • Isla de Cozumel, Cozumel; 20.5095, −086.9466; 7 m alt.; 5.XII.2020; amaymarrufo obs.; #66141565 • La Isla, Zona Hotelera, Cancún; 21.1123, −086.7680; 3 m alt.; 4.XII.2020; angelesporta obs.; #66091138 • Calle Siaan Kanab, Solidaridad; 20.6694, −087.0419; 11 m alt.; 4.I.2020; fam_marin_flores obs.; #37283551 • Calle Sucre, Chetumal; 18.5591, −088.2821; 16 m alt.; 5.X.2018; parrao6 obs.; #17214058 • Bacalar; 18.6598, −088.3994; 9 m alt.; 26.X.2013; carlos2 obs.; #443085 • Solidaridad; 20.6851, −087.1178; 10 m alt.; 12.II.2021; carlosviana_c obs.; #71578275 • Calle Gardenias, Solidaridad; 20.6581, −087.1050; 8 m alt.; 22.XII.2019; ugo1 obs.; #36852596 – **San Luis Potosí** • San Miguel, Tamazunchale; 21.2563, −098.7872; 161 m alt.; 25.IX.2020; posadas obs.; #61915056. **Sinaloa** • Colonia Burócrata, Culiacán; 24.8237, –107.3850; 53 m alt.; 1.VII.2017; xenarthro obs.; #7354675 – **Tabasco** • El Bajío 1era sección, Heróica Cárdenas; 17.9706, -93.3611; 27 m alt.; 16.XII.2021; jesus453 obs.; #103142892 • Amatitán; 18.1761, −093.0814; 8 m alt.; 5.XI.2020; anyfungi obs.; #64241292 • Bosques de la Sierra, Teapa; 17.5699, −092.9469; 35 m alt.; 25.IX.2020; alan568 obs.; #60688973 • Parrilla II; 17.8801, −092.9151; 9 m alt.; 9.XI.2019; luisvazquez obs.; #35507771 • Josefa Ortiz de Domínguez, Macuspana; 17.7638, −092.6035; 13 m alt.; 18.X.2019; alvarezyopescador obs.; #34555744 • Villahermosa; 18.0064, −092.8010; 8 m alt.; 16.X.2019; carlos773 obs.; #34468024 • Macuspana; 17.9132, −092.4792; 6 m alt.; 14.I.2019; alvarezyopescador obs.; #19642158 – **Tamaulipas** • Colonia Vergel de la Sierra, Ciudad Victoria; 23.7344, −099.1812; 385 m alt.; 25.IX.2020; damian_88 obs.; #60707098 – **Veracruz** • Emiliano Zapata; 19.4988, −096.8507; 1192 m alt.; 15.XI.2021; oscar226 obs.; #101188884 • Zacate Colorado; 20.4948, −097.5233; 69 m alt.; 25.X.2021; yajaira04 obs.; #99347798 • Calle Lluvia, Xalapa-Enríquez; 19.5236, −096.8667; 1209 m alt.; 7.X.2021; roberto651 obs.; #97488182 • Papantla; 20.4803, −097.2019; 96 m alt.; 7.XII.2016; eugeniog obs.; #9403624 • Calle Tajín, Papantla; 20.4526, −097.3321; 210 m alt.; 31.XII.2014; jaico obs.; #1154216 • Unión Obrera Campesina, Río Blanco; 18.8410, −097.1341; 1244 m alt.; 21.VIII.2021; patriciacst obs.; #92008824 – **Yucatán** • Conkal; 21.0520, −089.5159; 10 m alt.; 26.X.2021; graciela_navarro obs.; #99606666 • Tizimín; 21.4016, −087.8788; 9 m alt.; 22.X.2021; raulcastillo52 obs.; #99035606 • Mérida; 21.0706, −089.6000; 10 m alt.; 16.X.2021; ismael2909 obs.; #98377752 • Mérida; 21.0138, −089.5659; 8 m alt.; 23.VII.2021; aleocana obs.; #92380609 • Mérida; 20.7877, −089.5910; 15 m alt.; 30.VII.2021; nayla_cruz_fernandhez obs.; #89805085 • Mérida; 21.0937, −089.6261; 10 m alt.; 14.VII.2021; ignorantmoose obs.; #86991337 • Tixkokob;

20.9957, −089.3961; 12 m alt.; 21.I.2021; j1962_1941 obs.; #68412146 • Mérida; 21.0142, −089.5674; 10 m alt.; 9.I.2021; mayel obs.; #68279665 • Cholul, Mérida; 21.0476, −089.5528, 7 m alt. 6.I.2019; efra obs.; #19465827 • Tekik de Regil, Timucuy; 20.8136, −089.5625; 13 m alt.; 22.VII.2021; criscatz obs.; #88382655 • Tizimín; 21.1459, −089.1610; 21 m alt.; 6.XI.2019; elcaminomascorto obs.; #35412702 • Mérida; 21.0316, −089.5677; 8 m alt.; 19.XI.2019; asislacocer obs.; #35848137 • Valladolid; 20.6957, −088.2229; 25 m alt.; 7.VIII.2020; mk37 obs.; #55692876 • Mérida; 20.9923, −088.5698; 11 m alt.; 1.X.2020; trinchan obs.; #61627540 • Tizimín; 21.1455, −088.1496; 24 m alt.; 16.X.2020; elcaminomascorto obs.; #62708040 • Xcanatún; 21.0770; −088.6250; 9 m alt.; 15.VIII.2019; franciscomp48 obs.; #64566138 • Mérida; 21.0436, −088.6186; 8 m alt.; 22.XI.2020; fauna_maya obs.; #65423531 • Mérida; 21.0135, −088.5662; 6 m alt.; 12.XII.2020; aleocana obs.; #68137893.

Identification. A small species, up to 5 cm long. Head laterally expanded but not recurved posteriorly, dark brown, sometimes with pigmentation concentrated into two black patches. Dorsal ground color pale brown to yellow-tan. Black collar at the neck, which extends ventrally and is interrupted at each side of the creeping sole. Dorsum with three longitudinal stripes that start at the collar: a broad median and sharply demarcated black stripe and two lateral broad, diffuse, dark-brown stripes (Figs. 1A, 5). Ventral side light, with white creeping sole distinct but not delineated by longitudinal stripes (Jones and Sterrer 2005; Ducey et al. 2007).

Distribution in Mexico. Recorded from Campeche, Chiapas, Coahuila, Estado de México, Guerrero, Jalisco, Morelos, Nayarit, Nuevo León, Oaxaca, Quintana Roo, San Luis Potosí, Sinaloa, Tabasco, Tamaulipas, Veracruz, and Yucatán.

Key to species of hammerhead flatworms in North America based on external characters

1a Transverse dark band (collar) behind the head complete (Fig. 1A) or incomplete (Fig. 1B); head crescent-shaped (Figs. 1A, B); median stripe does not extend into the head region (Fig. 1A, B) **2**

1b Without a transverse dark band behind the head (Fig. 1C, D); head rounded (Fig. 1C) or, if it is crescent-shaped, the median stripe extends into the head region (Fig. 1D, E)..... **3**

2a Transverse dark band behind the head complete (Fig. 1A); body yellow, with bold and very conspicuous median stripe, and one set of much less conspicuous lateral stripes, one on each side of the median stripe (Fig. 1A); ventral side without stripes; <3 cm ..... ***Bipalium vagum***

2b Transverse dark band behind the head incomplete (Fig. 1B); body usually grayish brown or opaque yellow; with a very narrow median dark stripe and two sets of lateral stripes, the external ones being less conspicuous than the ones closer to the median one, which are very bold (Fig. 1B); ventral side with two diffuse longitudinal grayish stripes >5 cm ..... ***Bipalium kewense***

3a Head rounded (Fig. 1C); body yellow-brown, median stripe does not extend into the head region (Fig. 1C); body without lateral and ventral stripes (Fig. 1C)..... ***Bipalium adventitium***

3b Head crescent-shaped (Fig. 1D, E); median stripe extends into the head region (Figs. 4, 5); body with lateral stripes (Figs. 1D, E) **4**

4a Median stripe begins thin (Fig. 1D); lateral stripes very poorly defined (Fig. 1D); color pale brown (Fig. 1D); no ventral stripes; <10 cm..... ***Bipalium pennsylvanicum***

4b Median stripe begins lenticular in shape (Fig. 1E); lateral stripes bold, very conspicuous (Fig. 1E); color yellow dorsally and ventrally; (Fig. 1E); three ventral longitudinal stripes, one on each side of the creeping sole and a broader, more diffuse one on the creeping sole; often >10 cm .. ***Diversibipalium multilineatum***

Discussion

Bipalium kewense has been previously reported from Mexico by Winsor (1983), but the locality in the country was unspecified. The specimen on which this is based is in the Zoologisches Institut and Zoologisches Museum der Universität Hamburg (Hamburg, Germany) with the voucher number V10734. The data are "Mexico, in garden under old [indecipherable] Dr. Dampfl [or Dampf] and Rob. Muller. xi. 1928" (L. Winsor pers. comm.; specimen not examined by us). Therefore, we provide for the first time records of this species for 22 Mexican states.

Bipalium vagum has never been formally recorded for Mexico, so the records presented here are the first for the country and for 17 states.

The distribution patterns of both species correspond to the predictions made by Fourcade et al. (2022), who also used iNaturalist records. No hammerhead flatworms were recorded from the states of Aguascalientes, Baja California Sur, Chihuahua, or Sonora.

The iNaturalist platform has been recognized as a valuable tool for contributing to the knowledge of species' distributions (Chandler et al. 2017; Alzate-Cano and Hurtado-Pimienta, 2021). Given that hammerhead flatworm species recorded in North America can be confidently identified by photographs alone (when diagnostic features are visible), this citizen science app is appropriate to monitor their distribution on the continent, as it has been done previously for invasive (Hiller and Haelewaters 2019; Werenkraut et al. 2020) and endangered (Roux et al. 2019) species. However, although citizen science can be a very helpful tool, it cannot replace museum collections, and for this reason we decided to describe our collection and fixation techniques here.

Finally, we emphasize the need to study the genital structure of mature specimens of *Diversibipalium multilineatum* to properly assign it to one of the three

"natural" genera. Since many introduced land planarians reproduce only asexually outside of their place of origin or preferred climate, not developing sex organs, molecular studies can also help characterize a species and its phylogenetic position (Justine et al. 2018, 2022).

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Author's Contributions

Conceptualization: ML. Data curation: RGB, ML, PV. Formal analysis: ML, PV, RGB. Investigation: PV, ML, RGB. Methodology: ML. Resources: PB. Validation: PB. Visualization: PB. Writing – original draft: ML. Writing – review and editing: PB.

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